

Green roof substrate embodied energy and durability: A call for alternatives

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Outline

- Quick introduction to green roofs
- Current standards and requirements
  - FLL
  - ASTM
  - LEED
- Justification
- Methods
- Results
- Future Work

Green roof systems

- Green roofs are classified based on substrate depth
- Range of design intents

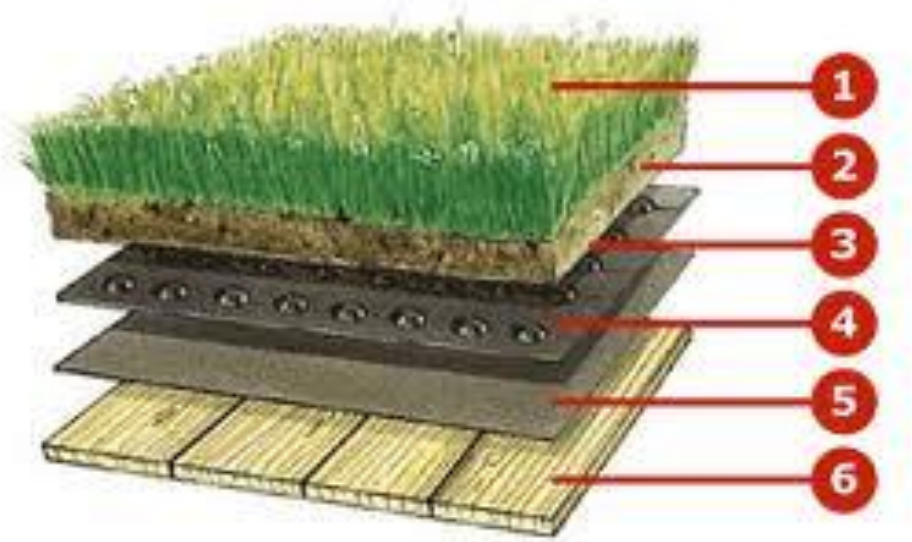


Image: tritonsystems.co.uk

Green Roof Classification

Intensive (cm)	Extensive (cm)	Reference
15-20	5-15	Kosareo and Ries (2007)
>50	N/A	Kohler et al. (2002)
15-35	3-14	Mentens et al. (2006)
>10	<10	Wong et al. (2007)
>30	N/A	Bengtsson et al. (2005)
>10	2-10	Graham and Kim (2005)

Source: Berndtsson, 2010

FLL Standards

- Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL)
- FLL is a German landscape industry green roof manual that has been adopted internationally

FLL Standards: Particle Size Distribution (PSD)

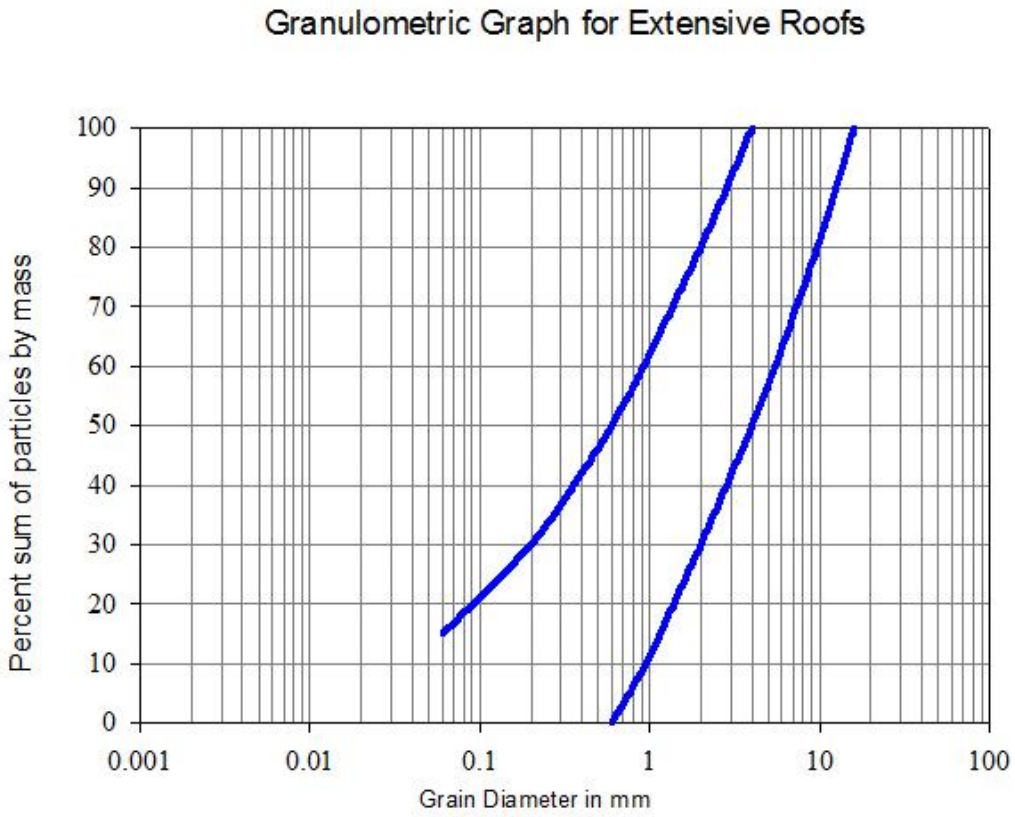


Image: Adapted from FLL 2008 English manual

FLL Standards: Organic matter

- ≤ 65 g/L for extensive substrates
  - FLL, 2008

Images: www.specialtysoil.com, www.soil-net.com and www.frenchgardening.com

FLL-based interpretations

- 33% humus, 33% sand, 33% pumice
  - Volumetric? Gravimetric?
  - Canada Public Works Board, 2002
- 6-8% organic and 15-20% organic, different paragraphs
  - Sydney City Council Green Roof Resource Manual, 2010
- 4% or 6%, by construction
  - Loss on Ignition
  - City of Seattle, 2010

FLL Standards: Frost resistance

- 10.2.3 Frost Resistance (FLL, 2008)
  - “Must be insured by the manufacturer”
  - Based on components subjected to high levels of static and/or dynamic stress
  - No methodology or allowable particle loss is suggested

Image 1: www.sln.org.uk

ASTM standards

- E2396: Saturated water permeability of granular drainage media
- E2397: Determination of dead and live loads
- E2398: Water capture and media retention of drain layers
- E2399: Maximum media density for dead load analysis
- E2400: Selection, installation, and maintenance of green rof plants

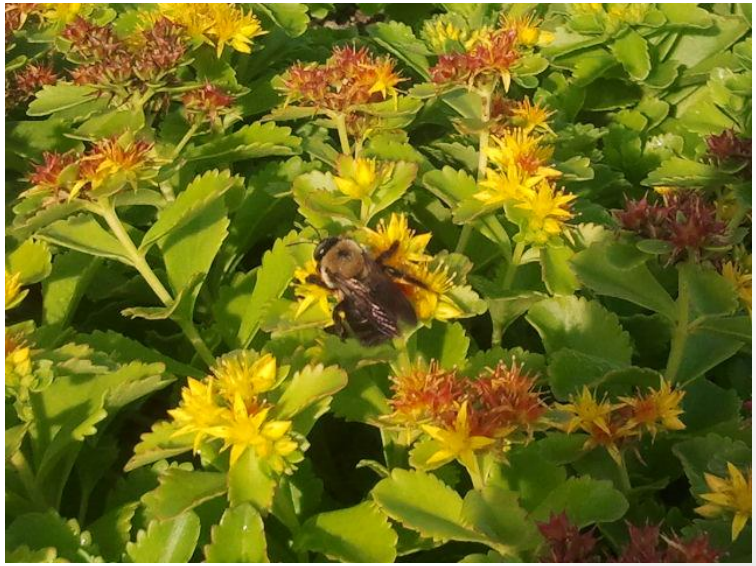
Image: www.astm.org

ASTM: ESCS specifications

- ASTM E-2788: Specification for use of ESCS as a mineral component in growing media and drainage layer of GR systems

LEED

- LEED points sometimes drive green roof implementation
  - Restore or protect habitat: 1 point
  - Stormwater quantity control: 1 point
  - Heat island effect (roof): 1 point
  - Rainwater management: 1 point
- If it looks good, it must be good!



Are Green Roofs Really Green?

- Expanded slate embodied energy ~ 0.44kg CO_2/kg
  - Hammond and Jones, 2008; Expanded Shale, Clay, and Slate Institute Information Sheet 6001
- 6 cm substrate at density of 1600kg/m^3 has 5.76kg C/m^2
- Total system embodied energy is 6.6kg C/m^2
- 86% attributed to the substrate!
  - Getter et al., 2009

Image: organic-mama.ca

Green Roofs and Carbon

- Getter et al. (2009) quantified green roof carbon sequestration
  - Substrate: 100g C/m^2
- 9 years to break even with system carbon cost, energy savings
  - Sailor, 2008
- 7 years to break even after quantifying sequestration.

Justification

Justification

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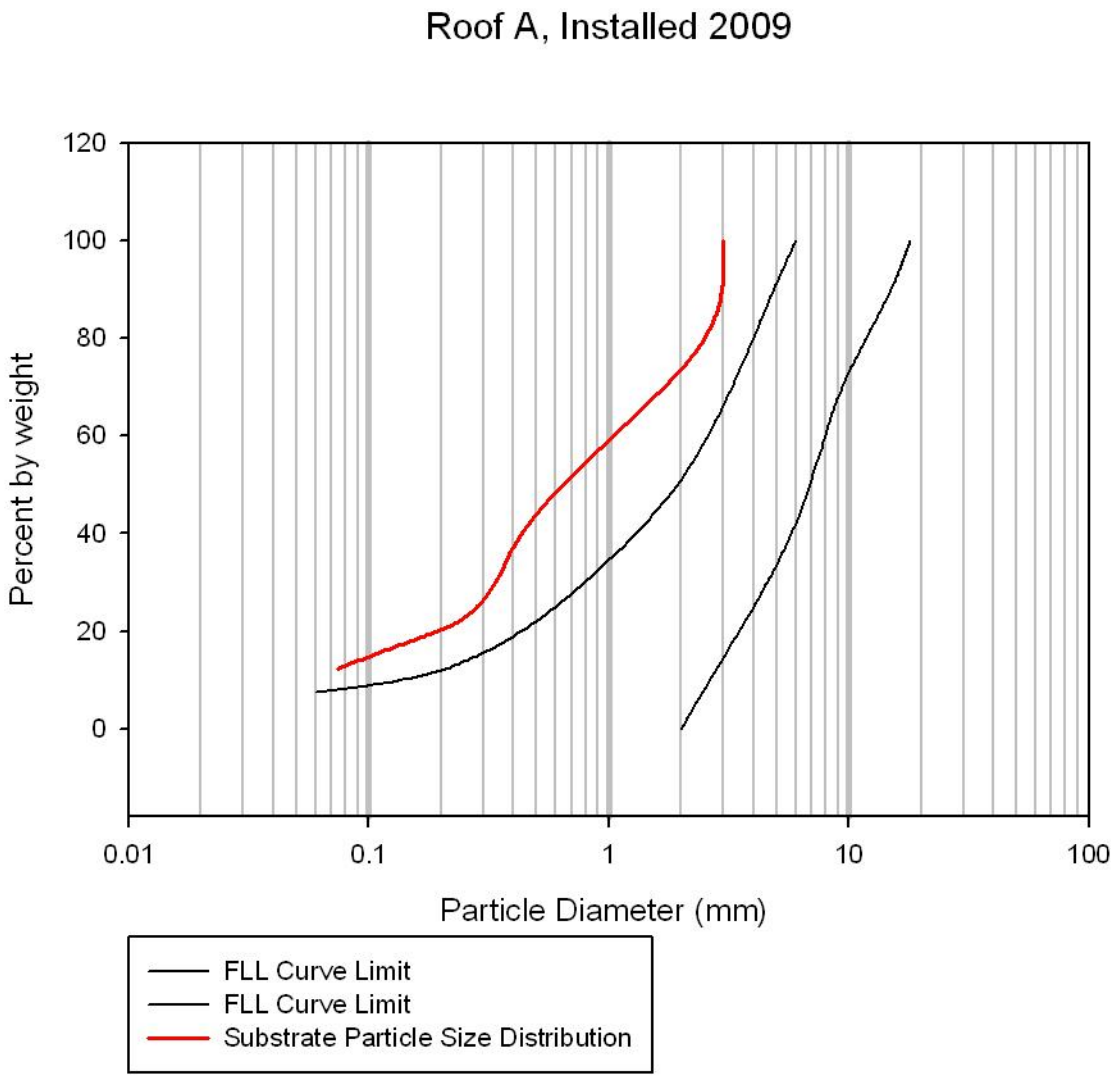
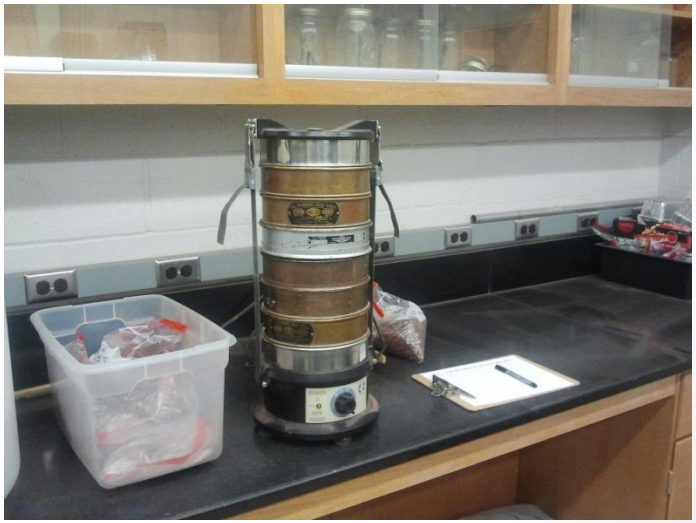
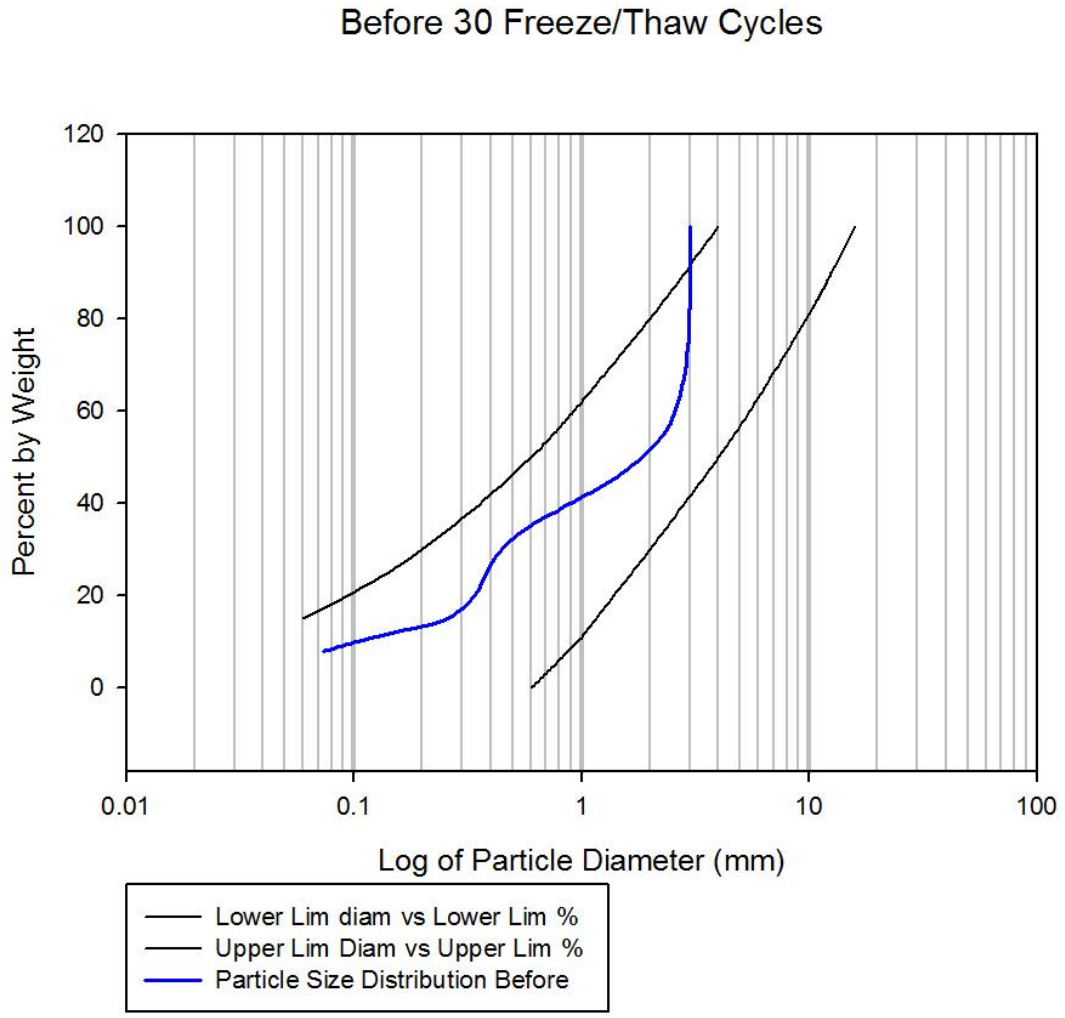

Roof A, Installed 2009
120
100
80
60
40
20
0
Percent by weight
0.01
0.1
1
10
100
Particle Diameter (mm)
FLL Curve Limit
FLL Curve Limit
Substrate Particle Size Distribution

Methods

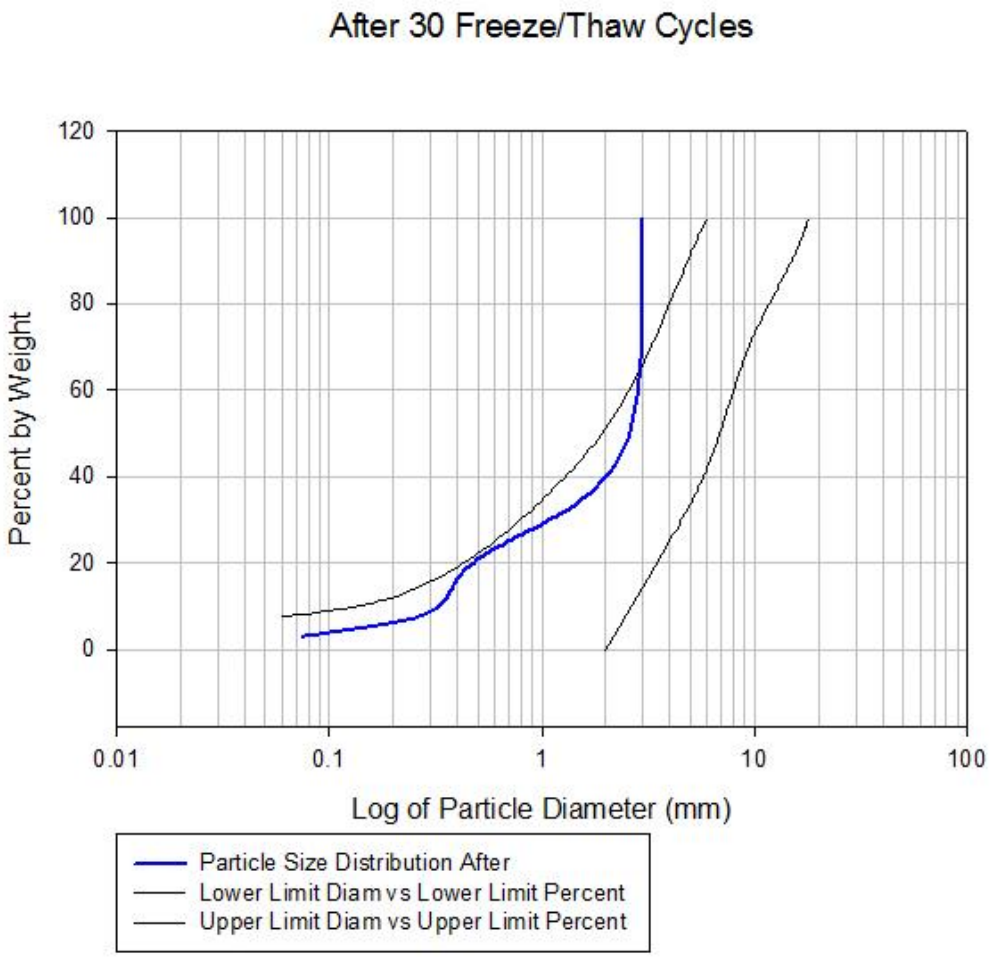
- Obtain a sample direct from the substrate manufacturer and perform PSD analysis before and after 30 freeze/thaw cycles



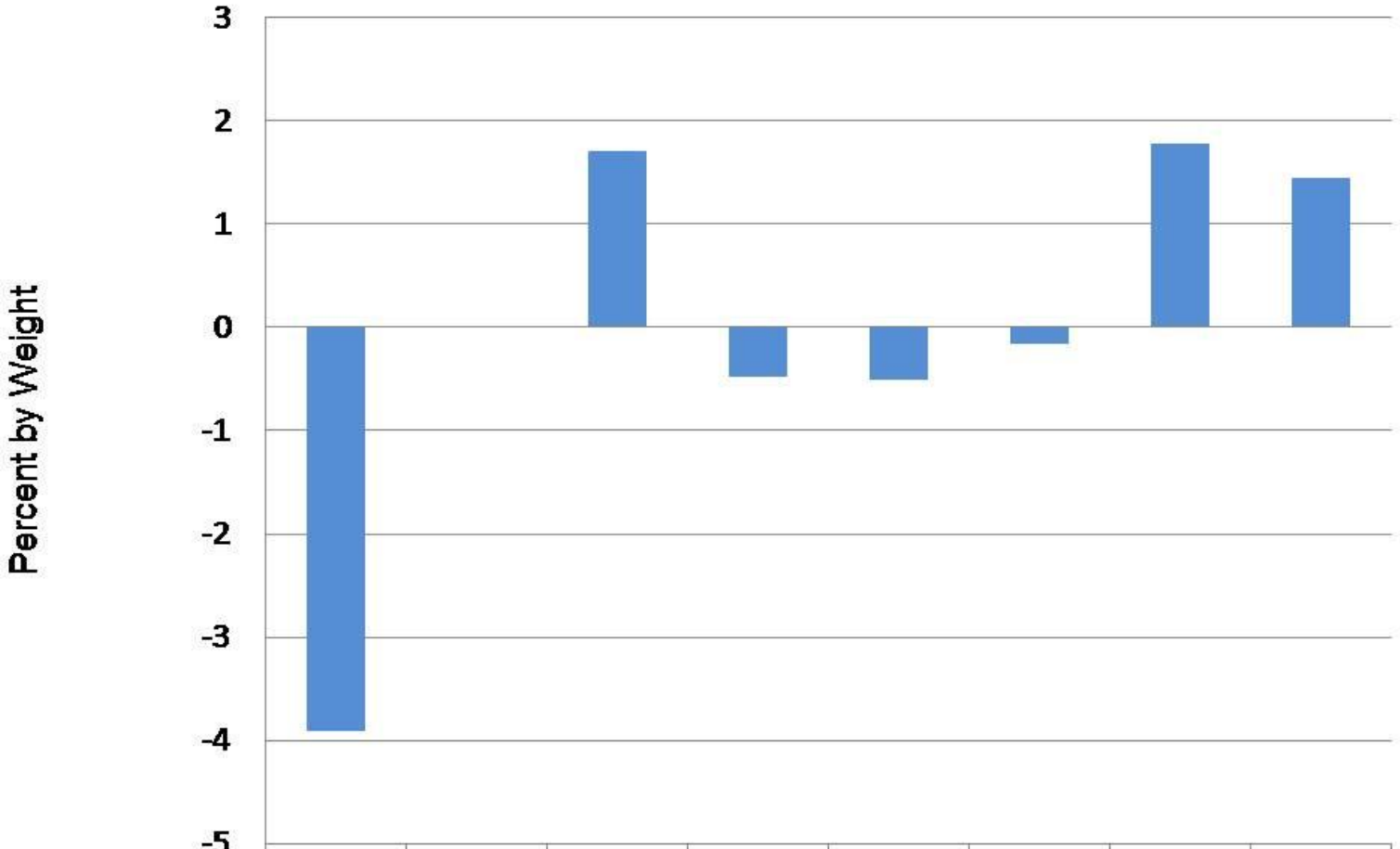
Results: Before 30 cycles



Results: After 30 cycles



Percent weight differences of standard heat-expanded mineral substrate in 8 different particle sizes after 30 freeze-thaw cycles.



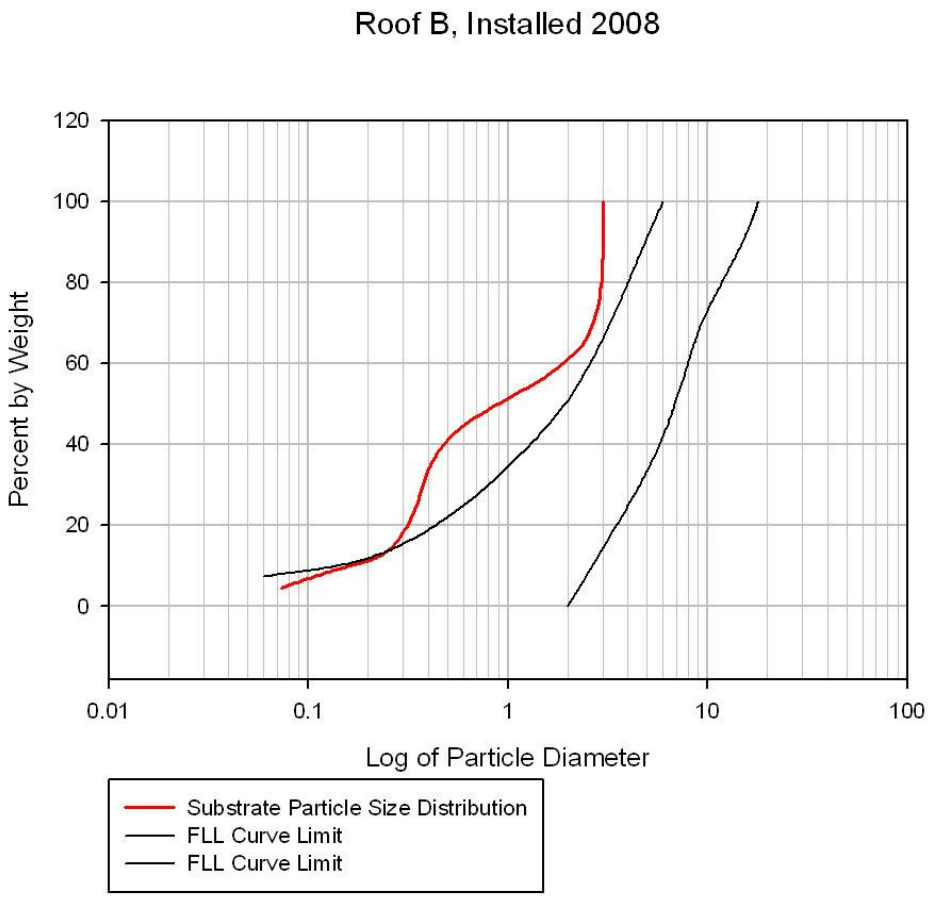
	>24.6 mm	1.19-24.6 mm	0.60-1.19 mm	0.35-0.60 mm	0.16-0.35 mm	0.15-0.16 mm	0.075 - 0.16 mm	<0.075 mm
Percent Weight Difference	-3.9	0	1.7	-0.47	-0.5	-0.15	1.77	1.44

Mature roof sampling

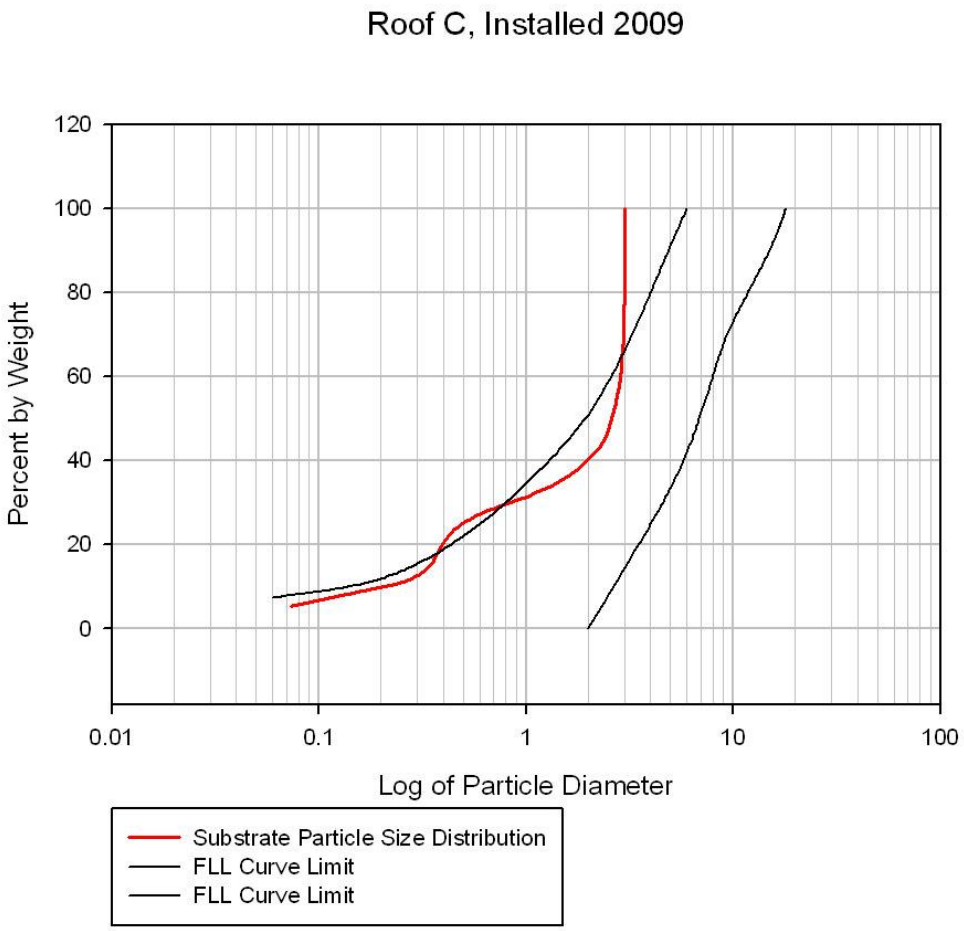
- Sample 3-7 year old green roofs in the Mid-Atlantic, representing the major commercially available substrate blends
- Determine particle size distribution



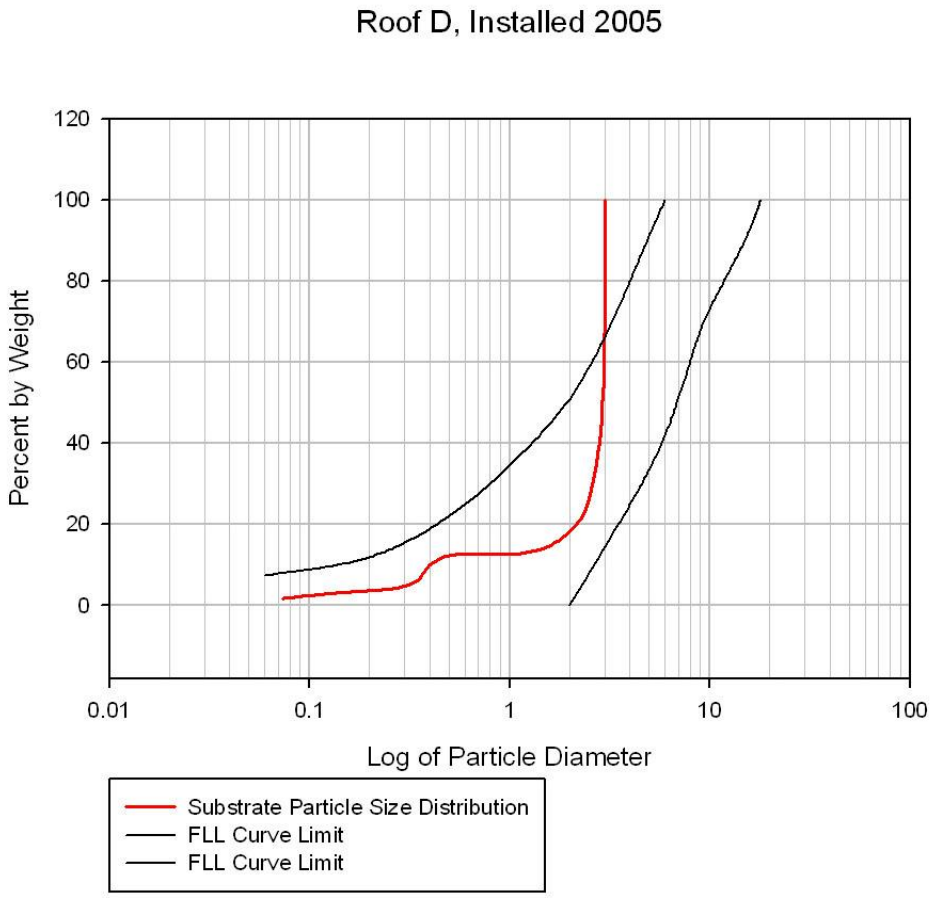

Results


Roof B, Installed 2008
120
100
80
60
40
20
0
Percent by Weight
0.01
0.1
1
10
100
Log of Particle Diameter
Substrate Particle Size Distribution
FLL Curve Limit
FLL Curve Limit

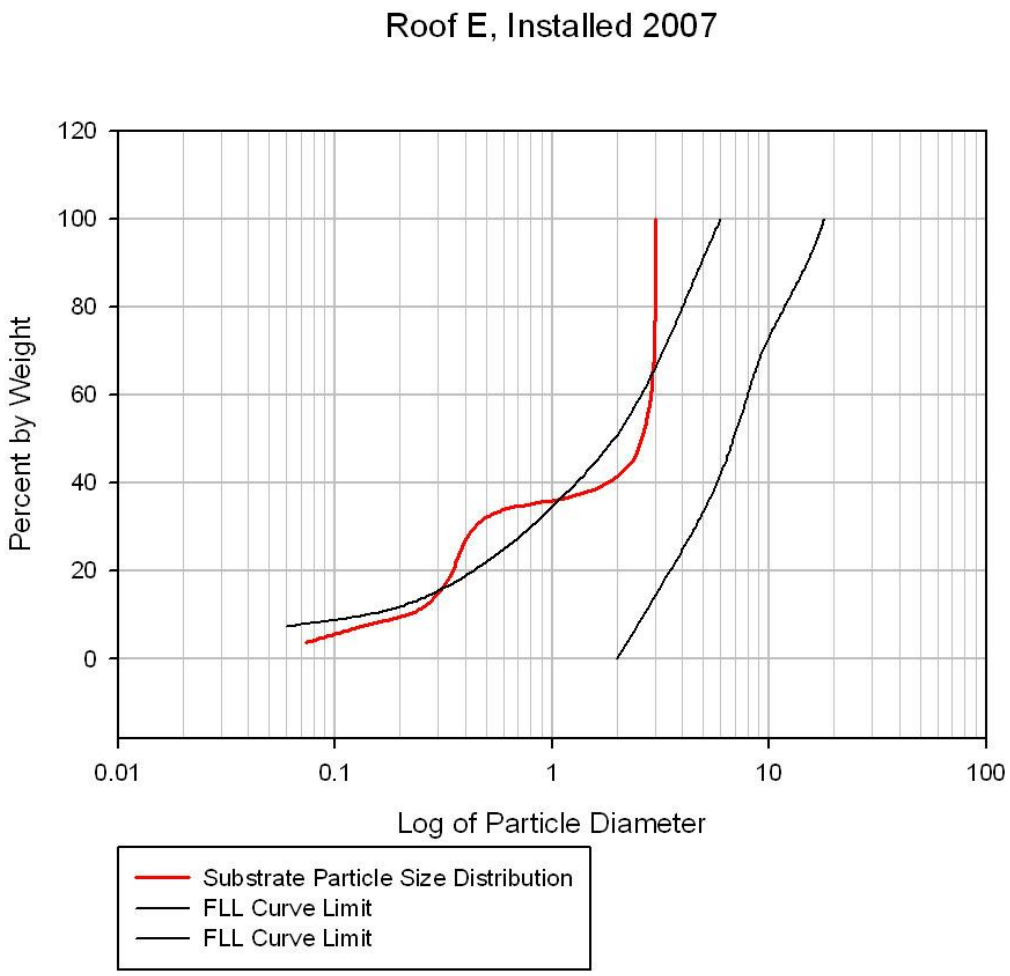
Results


Roof C, Installed 2009
120
100
80
60
40
20
0
Percent by Weight
0.01
0.1
1
10
100
Log of Particle Diameter
Substrate Particle Size Distribution
FLL Curve Limit
FLL Curve Limit

Results


Roof D, Installed 2005
120
100
80
60
40
20
0
Percent by Weight
0.01
0.1
1
10
100
Log of Particle Diameter
Substrate Particle Size Distribution
FLL Curve Limit
FLL Curve Limit

Results


Roof E, Installed 2007
120
100
80
60
40
20
0
Percent by Weight
0.01
0.1
1
10
100
Log of Particle Diameter
Substrate Particle Size Distribution
FLL Curve Limit
FLL Curve Limit

Discussion

- Standards are imposed at the time of or prior to installation
- 5 roofs represent 4 major commercially available substrates
- None met FLL granulometric guidelines 3-7 years post-installation
- Popular commercial media demonstrated particle fracturing after 30 freeze/thaw cycles
- These materials are not durable and cost 0.44 kg CO_2/ kg media

Future Work

- Short term: Analyze 3 additional commercially available materials, straight from the manufacturer

- Long term: Develop a durable, locally-available green roof substrate that will maintain the desired characteristics for optimal plant growth.

Acknowledgements

- Maryland Department of Natural Resources
- Furbish Company
- Maryland Industrial Partnerships

Literature

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Questions?